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A Solid-State Approach to Crankcase Heaters

J. C. Williams
Texas Instruments

A SOLID STATE APPROACH
TO
CRANKCASE HEATERS

JAMES C. WILLIAMS, P.E.

WHY USE A CRANKCASE HEATER

In air conditioning and refrigeration systems using hermetically sealed compressors the motor and compressor mechanisms are encapsulated within a common enclosure. This means that there are two fluid mediums within the same enclosure or system; the refrigerant, which is normally in the gaseous state when in the compressor, and the compressor lubrication oil which is a liquid and therefore under normal conditions drains to the sump of the compressor where it is taken in by the oil pump and circulated through the lubrication system.

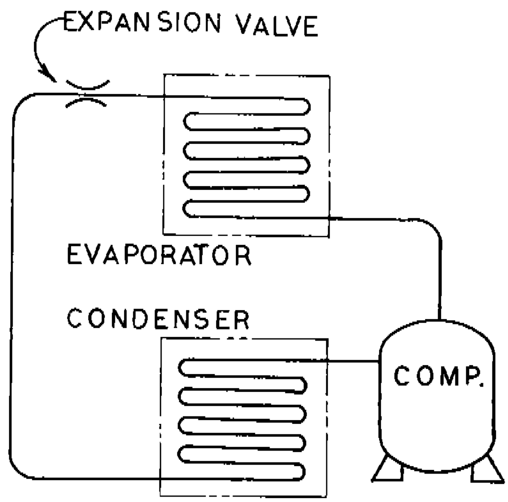


FIGURE 1

It is the nature of a refrigerant and oil mixture within a system that the refrigerant will be attracted by the oil. The vapor will migrate through the system and upon reaching the oil in the compressor will condense and mix with the oil until it is completely saturated. This phenomenon is attributed to a difference in vapor pressures of the refrigerant and the oil and will occur even when there is no pressure nor temperature differential to force the migration. For example: If a system is allowed to completely equalize at room temperature, the refrigerant and oil mixture will be approximately 70% refrigerant.

Another phenomenon which may cause refrigerant condensation in the compressor is due to refrigerant migrating to the coolest components of the air conditioning system, i. e., due to the lower pressure caused by the cooler temperature the refrigerant is forced to that component. If that component happens to be the compressor then the compressor sump is where the refrigerant accumulates. Since the compressor and condenser are located outdoors, they will be exposed to low ambients during long periods of shutdown for the winter months. It is during these long periods that excessive migration can take place.

There are other ways in which liquid refrigerant can accumulate in the compressor such as incomplete evaporation, an improperly applied or defective expansion valve, or too much refrigerant for the design of the system. Whatever the cause, excessive refrigerant in the oil will boil violently due to the sudden drop in pressure when the compressor is started. This boiling and foaming action can deprive the system of adequate lubrication and cause bearing failure. In more severe cases the liquid refrigerant could cause the compressor to "slug" (try to compress the liquid refrigerant) which is likely to cause damage to the valves or pistons.

A crankcase heater is not meant to be a "cure all". It is not meant to protect against large volumes of liquid but is effective in controlling migration. By heating the refrigerant to some point above its evaporating temperature the crankcase heater causes an increase in pressure in the compressor reservoir driving excess refrigerant to other parts of the system such as the cooler condensing coil.

WHAT ARE THE REQUIREMENTS OF CRANKCASE HEATERS

Most crankcase heaters in the past have been of the resistance type. A resistance wire was enclosed in a protective sheath and wrapped around the base of the compressor at the oil level. Unless some external means of controlling the power was used, the heater remained at full power output regardless of other conditions such as oil temperature or ambient temperature.

Enough heat must be generated by the crankcase heater to maintain the oil reservoir at some temperature higher than either the evaporator or the condenser coil. This will help to hold the refrigerant in either of these units rather than allowing migration to the compressor. One manufacturer recommends that a temperature differential between ambient and compressor oil be approximately 10°F. However, Underwriters' Laboratory Standard 465 states that the maximum allowable temperature for the hermetic compressor and motor enclosure shell, including the surface of a crankcase heater, shall be 150°C or 302°F. Therefore the ideal heater must generate enough power to heat the oil to something over 50°F in a 40°F ambient, and to about 90°F at 80°F outdoor ambient but still maintain a maximum surface temperature of 150°C.

Therefore, the ideal heater would heat the compressor to the desired temperature and then modulate the output power to where it only replaced the heat lost.

Since there are many different sizes and shapes of compressors, the mounting of the compressor heater should be versatile to enable the air conditioner manufacturer to stock a minimum of different combinations of wattage ratings and mounting requirements. It is common for a large air conditioner manufacturer to require several different sizes and configurations of heaters.

WHAT IS THE SOLID STATE APPROACH

This approach utilizes a ceramic heating element that generates output power that varies inversely

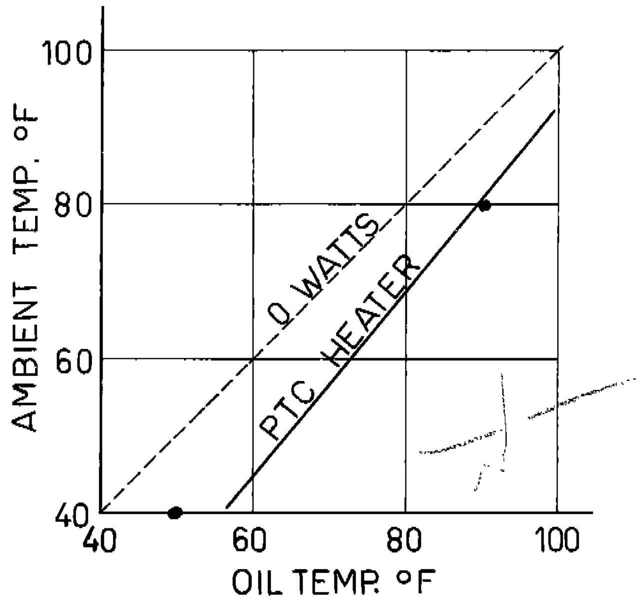


FIGURE 2

with the temperature of the element because of the Positive Temperature Coefficient (PTC) of the doped barium titanate material.

This material's resistance is relatively constant up to its anomaly temperature, which in this case is 120°C, where it increases markedly several orders of magnitude over a relatively small increase in temperature. Thus, upon application of a voltage the current through the heating element generates power rapidly (I^2R) until the temperature increases to within a few degrees of the anomaly temperature of 120°C. At this point, a sudden resistance increase restricts current flow, and thus the I^2R power generated, to a stabilization point where the power generated is only that necessary to hold the temperature constant.

If changes in the system occur, the heater almost instantly self-compensates for the change. A voltage drop, for example, will cause a corresponding decrease in power and the heater will begin to cool. As it cools, the resistance drops allowing more current to flow generating the necessary I^2R to restabilize the heater at the anomaly temperature. An over voltage condition has the opposite effect.

Another variable is temperature. Again, just as with other parameters, a change in the temperature will cause a corresponding change in resistance which will allow the heater to self-compensate and adjust its power output level back to equilibrium.

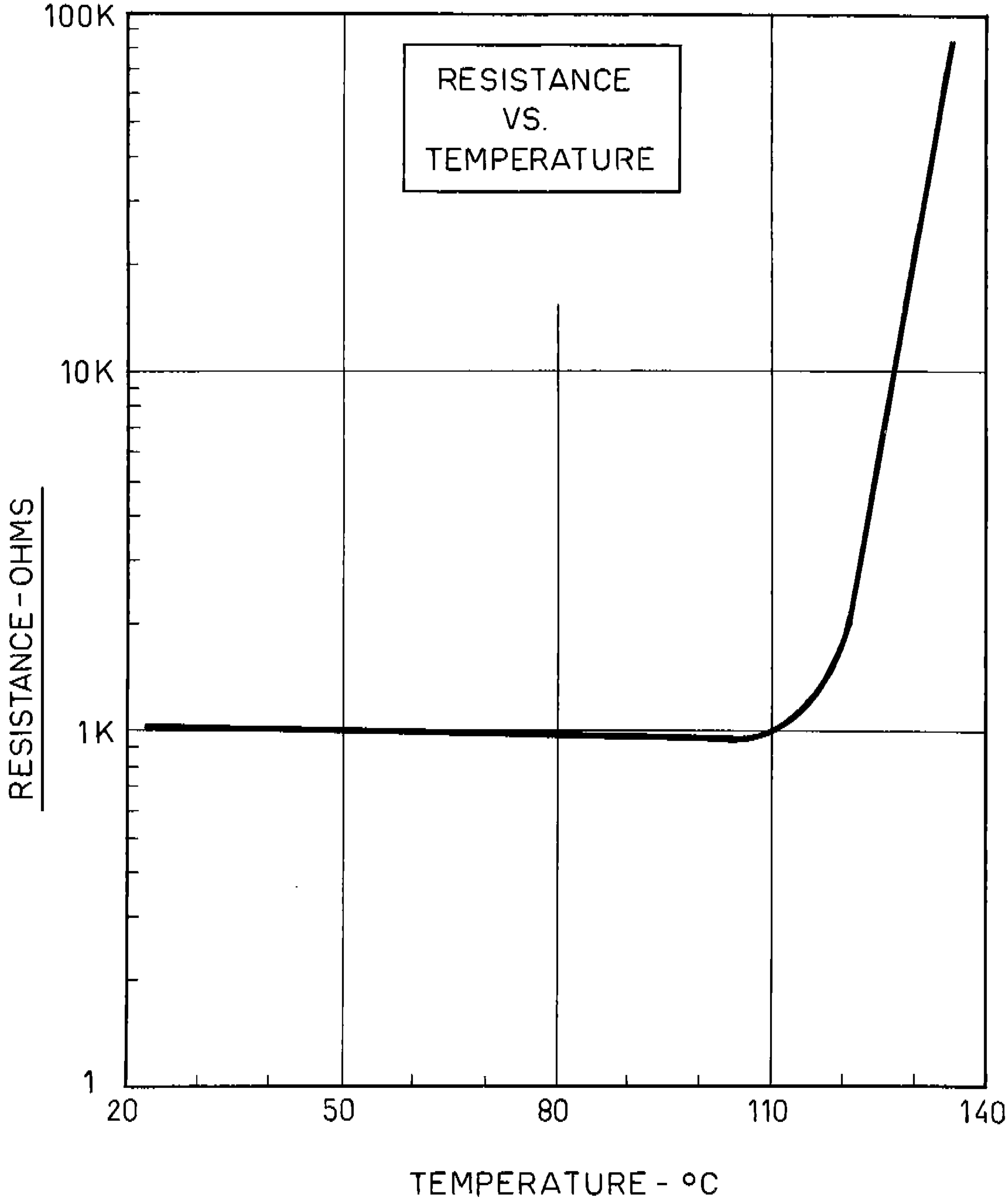

RESISTANCE
VS.
TEMPERATURE
100K
10K
1K
1
RESISTANCE - OHMS
20
50
80
110
140
TEMPERATURE - °C

FIGURE 3

The net result is a heater that, within reasonable limits, is satisfied to exist within a very small temperature band. An external disturbance that would otherwise change this temperature is automatically compensated for.

WHAT ARE THE RESULTS OF THE SOLID STATE APPROACH

With the previously discussed parameters in mind, a heater was developed, tested and approved by a major air conditioning manufacturer as performing to their specifications.

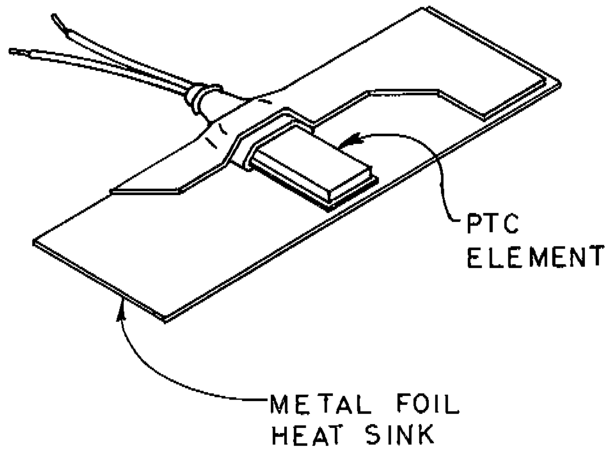


FIGURE 4

As can be seen from the illustration, a pill of PTC material is mounted on a metal plate to provide both a means of conducting electricity and a heat sink for more efficient heat transfer. The other lead is mounted to the top of the pill and the entire assembly is encapsulated within a moisture proof plastic insulation. This assembly in turn is sandwiched between two layers of metal foil with an adhesive on one side. This provides a very efficient means of heat distribution and a means of mounting.

As mentioned earlier, and shown in Figure 2, the ideal heater would generate only enough power to maintain the compressor oil at about 10°F above ambient, but near zero power is necessary at ambients near 90°F. Tests run on a three horsepower compressor showed that the PTC heater maintained the oil 16°F above the 40°F ambient and 7.5°F above the 90°F ambient, very close to ideal performance. More significant however is the fact that the PTC heater achieved these results with only a fraction

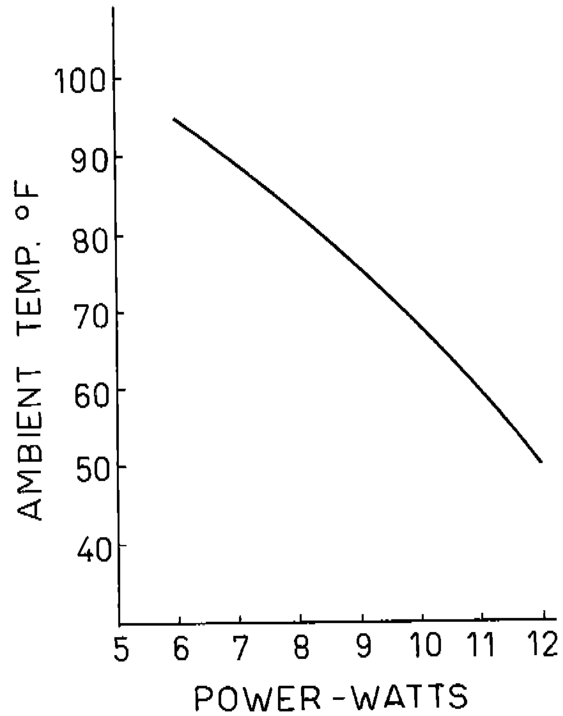


FIGURE-5

of the power generated by an ordinary resistance heater.

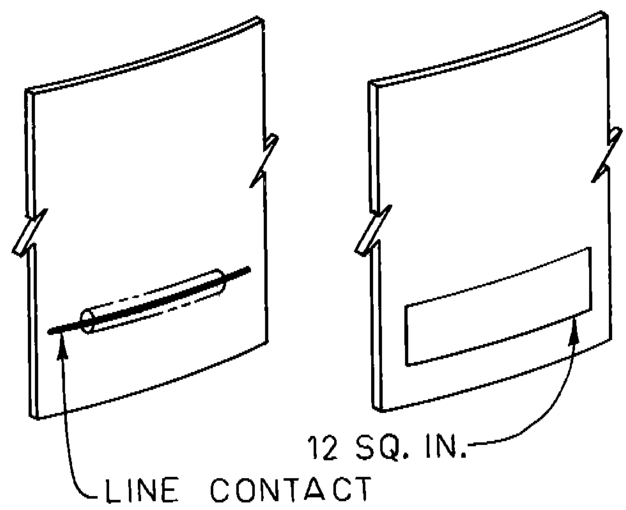
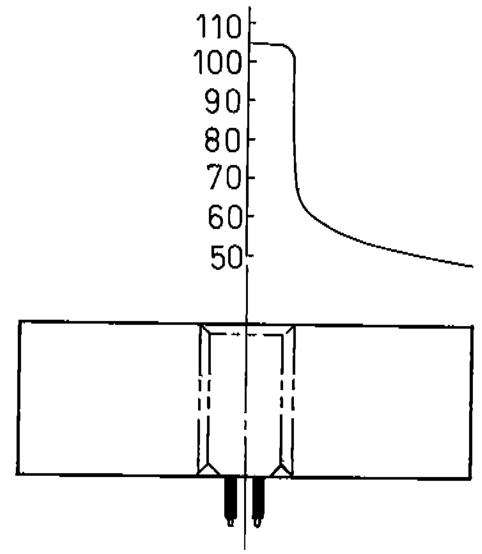


FIGURE-6

The main reason for this improvement in performance can be attributed to the relative efficiencies of the two types of units. The surface contact of the heaters to the compressor wall is quite different; the wrap around resistance heater being very near line contact because of the round sheath against a flat surface. If other factors are considered equal, then the amount of heat transferred is directly proportional to the area of the surfaces in contact, the larger area of the PTC crankcase heater contributes immensely to the efficiency of the heater.

Another of the ideal parameters set forth was that the heater should not overheat to the point where it would cause oil breakdown or possible damage to other wiring that may contact the heater. Because of the self-compensating nature of PTC, the heater acts as though it has a built-in thermostat to regulate its temperature.

The maximum temperature of the heater pill itself is approximately 120°C (248°F) and the external surface ranges from 105°C at the hottest point to about 50°C near the edge of the heat sink foil. This puts all heaters made from this material well within safe limit regardless of the size of the compressor or its oil capacity.



TEMPEPATURE PROFILE - °C

FIGURE - 7

The mounting of the heater is extremely versatile. Because of the adhesive back it can mount on the side or the bottom of a compressor and can mount on virtually any shape regardless of whether the mounting feet extend up into the oil level area. This can be seen from Figure 8.

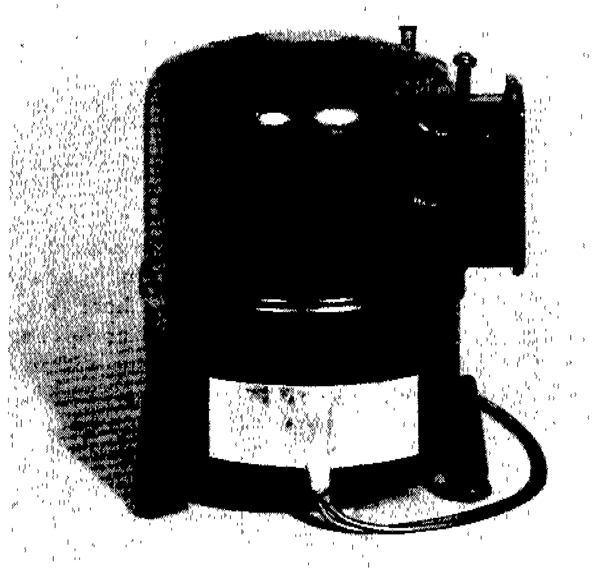


FIGURE - 8

OTHER FEATURES INHERENT IN PTC CRANKCASE HEATERS

1. During brownout or low voltage conditions that occur during peak operating periods, the compressor starting and running torque are reduced considerably since torque varies as the square of voltage. At the same time the current is reduced to some level between running overload and nominal voltage locked rotor current causing the motor to heat up and trip the overload protector. This nuisance tripping is frustrating enough but if the compressor is equipped with an ordinary resistance type heater, it is probably adding a minimum of 45 to 50 watts heat to the compressor compartment which would delay the cool-down of the motor winding and a reset of the motor protector.

   In addition the drop of voltage during the brownout will have no adverse affect on the PTC heater, for example: The 240 VAC heater can be operated within plus or minus 15% rated voltage with essentially no change in performance.

2. The Air Conditioning and Refrigeration Institute Standard 210-66 requires that a unitary air conditioner be placed in a 90°F dry bulb chamber and a voltage of 90% name plate be applied. Then the power to the air conditioner is interrupted for a period long enough for the compressor to stop but not over five seconds. Power is then immediately restored. Since the compressor is trying to start against unequalized pressure, and since it is at low voltage and extremely hot, the motor protector will trip the compressor off the line. ARI requires that within two hours following the power interruption, the unit will resume continuous operation. The fact that the PTC crankcase heater is supplying less than six watts at this temperature will aid in meeting the ARI requirements.

CONCLUSION

Because of the unique characteristics of this new concept in crankcase heaters it is winning the approval of both air conditioner manufacturers and compressor manufacturers. By acting as though it had a built in thermostat, the heater effectively heats the compressor base to the desired temperature by replacing only lost heat and also prevents the possibility of overheating the compressor oil.

The variation of the resistance of the material with temperature contributes to the conservation of electrical power during peak operating periods. In addition, this feature can contribute power conserved to the overall efficiency of the air conditioning package.

Thus, this approach to crankcase heaters seems to be an ideal application for the PTC ceramic material.